# INDOOR AIR QUALITY ASSESSMENT

**Uxbridge Early Learning Center**
**At The Good Shepard School**
**11 Church Street**
**Uxbridge, MA 01569**

Prepared by:
Massachusetts Department of Public Health
Center for Environmental Health
Emergency Response Indoor Air Quality Program
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## Background/Introduction

At the request of the Uxbridge School Department (USD), the Massachusetts Department of Public Health's (MDPH) Center for Environmental Health (CEH) provided assistance and consultation regarding indoor air quality at each of Uxbridge's public schools. These assessments were coordinated through Michael Legender, Facilities Director for the USD. On June 15, 2005, Sharon Lee, an Environmental Analyst in CEH's Emergency Response/Indoor Air Quality (ER/IAQ) Program, conducted an assessment at the Uxbridge Early Learning Center (ELC) at the Good Shepherd School, 11 Church St, Uxbridge, Massachusetts.

The ELC is located in a two-story, eight-classroom, white clapboard schoolhouse constructed circa 1921. The building was originally used by the Church of the Good Shepherd as a school from 1921 to 1972. The building was renovated in 2004, at which point the USD began leasing the building for its ELC facility. All kindergarten classes and two pre-kindergarten classes were relocated to this building from the Taft Elementary School in September 2004. The basement of the building is occupied. Windows are openable throughout the building.

## Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector

(PID). CEH staff also performed a visual inspection of building materials for water damage and/or microbial growth.

## Results

The ELC houses a pre-kindergarten and kindergarten student population of approximately 200 and a staff of approximately 20. Tests were taken under normal operating conditions. Test results appear in Table 1.

## Discussion

### Ventilation

It can be seen from Table 1 that carbon dioxide levels were elevated above 800 parts per million (ppm) in 1 of 10 areas surveyed, indicating adequate air exchange in the majority of areas surveyed the day of the assessment; however, no mechanical fresh air supply exists in the building. Fresh air is provided solely by openable windows. A number of areas with carbon dioxide levels below 800 ppm had windows open. Most of the classrooms had normal occupancy levels, but a few rooms were sparely populated. Low occupancy and open windows can reduce carbon dioxide levels. Carbon dioxide levels would be expected to be higher with full occupancy and with windows closed.

Ventilation in the school was originally provided to classrooms by a natural gravity ventilation system, which distributed rising heated air via a process known as the stack effect. Both the supply and exhaust components to the system appeared to have been sealed (Pictures 1 and 2). However, it appears that either prior to or during the 2004 renovations, gravity exhaust vents in coat closets were mechanized with rooftop fans (Pictures 3 and 4). At the time of this assessment, the exhaust fans were operating. However, a number of exhaust vents were blocked with various items (Picture 5). In order to function as designed, exhaust vents must remain free of obstructions.

Although the classrooms lack mechanical ventilation, many classrooms are equipped with window-mounted air conditioners (ACs) that can supplement windows to introduce outside air. Each of these ACs has a ‘fan only’ setting that allows the equipment to provide a limited amount of fresh outside air (without cooling). Consideration should be given to operating ACs in the fan only setting as a means for providing fresh air to classrooms when windows cannot be opened (e.g., adverse weather conditions).

To maximize air exchange, the MDPH recommends that ventilation equipment operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). Since the building is only equipped with exhaust capabilities, this recommendation does not apply in this situation

The Massachusetts Building Code requires that each room have a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or openable windows (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The MDPH uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information on carbon dioxide see Appendix A.

Temperature readings ranged from $66^{o}$ F to $74^{o}$ F (Table 1), with two areas below the MDPH comfort guidelines. The MDPH recommends that indoor air temperatures be maintained in a range of $70^{o}$ F to $78^{o}$ F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. It is also difficult to control temperature and maintain comfort without operating the ventilation equipment as designed (i.e., abandonment of the original ventilation system).

The relative humidity measurements ranged from 43 to 64 percent, which were within the MDPH recommended comfort range in all but one area. The MDPH recommends a comfort range of 40 to 60 percent for indoor air relative humidity. While temperature is mainly a comfort issue, relative humidity in excess of 70 percent for extended periods of time can provide an environment for mold and fungal growth (ASHRAE, 1989). Relative humidity levels in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

**Microbial/Moisture Concerns**

A few areas had water-stained ceiling plaster, which can indicate leaks from the roof or plumbing system. Water-damage to porous building materials can provide a source for mold growth, especially if wetted repeatedly. Water damaged building materials should be repaired/replaced after a water leak is discovered and repaired.

Plants were observed in a number of areas (Picture 6). Plants, soil and drip pans can serve as sources of mold growth, thus should be properly maintained. Over-watering of plants should be avoided and drip pans should be inspected periodically for mold growth. Plants should also be located away from univents and ventilation sources to prevent aerosolization of dirt, pollen or mold.

A number of sources for water penetration were observed around the exterior of the building including open utility holes, damaged flashing and missing damaged mortar around exterior brick (Pictures 7 to 10). In addition, several rubber gaskets for basement level windows were no longer intact (Picture 11). Each of these breaches are points through which water can penetrate the building, particularly under driving rain conditions. Continued freezing and thawing of water during cooler months will serve only to cause further damage. Over time, these conditions can undermine the integrity of the building envelope and provide a means of water entry into the building by capillary action through foundation concrete and masonry (Lstiburek & Brennan, 2001). Breaches can also serve as points of entry or shelter for pests.

### Other IAQ Evaluations

Indoor air quality can be negatively influenced by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants. Common combustion emissions include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, MDPH staff obtained measurements for carbon monoxide and PM2.5.

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. Several air quality standards have been established to address carbon monoxide and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

The American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) has adopted the National Ambient Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems

(ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from six criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000a). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS levels (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000a).

*Carbon monoxide should not be present in a typical, indoor environment*. If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels. On the day of assessment, outdoor carbon monoxide concentrations were non-detect (ND) (Table 1). Carbon monoxide levels measured in the school were also ND (Table 1).

The US EPA has established NAAQS limits for exposure to particulate matter. Particulate matter is airborne solids that can be irritating to the eyes, nose and throat. The NAAQS originally established exposure limits to particulate matter with a diameter of 10 μm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 microgram per cubic meter ($\mu g/m^3$) in a 24-hour average (US EPA, 2000a). These standards were adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent PM2.5 standard requires outdoor air particle levels be maintained below 65 $\mu g/m^3$ over a 24-hour average (US EPA, 2000a). Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, MDPH uses the more protective PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations were measured at 9 μg/$m^3$ (Table 1). PM2.5 levels measured within the school ranged from 6 and 23 μg/$m^3$, which were below the NAAQS of 65 μg/$m^3$. Frequently, indoor air levels of particulates can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulates during normal operation. Sources of indoor airborne particulate may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices, operating an ordinary vacuum cleaner and heavy foot traffic indoors. The PM2.5 levels measured in this building would be expected in light of the lack of mechanical fresh air supply necessary for dilution of indoor particulate matter.

Indoor air quality can also be negatively influenced by the presence of materials containing volatile organic compounds (VOCs). VOCs are carbon-containing substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. An outdoor air sample was taken for comparison. Outdoor TVOC concentrations were ND (Table 1). Indoor TVOC concentrations were also ND (Table 1).

Please note, TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of TVOC containing products. In an effort to identify materials that can potentially increase indoor TVOC concentrations, MDPH staff examined classrooms for products containing these respiratory irritants. Cleaning products were found on countertops and in unlocked cabinets beneath sinks in some classrooms. Cleaning products contain VOCs and other chemicals that can be irritating to the eyes, nose and throat of sensitive individuals. These products should be stored properly and kept out of reach of students.

Several other conditions that can affect indoor air quality were noted during the assessment. Filters for portable air conditioners (ACs) and fan blades for personal fans were observed to have accumulated dust (Pictures 12 and 13). Re-activated ACs can aerosolize dust accumulated on filters. These filters should be changed or cleaned as per the manufacturer's recommendations, or more frequently if necessary. Re-activated personal fans can also result in aerosolization of accumulated dust. In addition, a number of surfaces throughout the school were found with accumulated dust. Dust can be irritating to the eyes, nose and respiratory tract. Flat surfaces should be wet wiped and cleaned with a vacuum equipped with the high efficiency particulate arrestance (HEPA) filter on a regular basis.

Accumulated chalk dust was also observed in some classrooms (Picture 13). Chalk dust is a fine particulate that can easily become aerosolized, irritating eyes and the respiratory system. Chalk trays should be wet wiped and cleaned regularly to prevent chalk dust buildup.

Lastly, pest attractants were identified within the building. Food-based projects and re-use of food containers were observed. Proper food storage is an integral component in maintaining indoor air quality. Food should be properly stored and clearly labeled. Reuse of food containers is not recommended since food residue adhering to the surface may serve to attract pests.

## Conclusions/Recommendations

In view of the findings at the time of the visit, the following recommendations are made to improve general indoor air quality:

1. Consult an HVAC engineer concerning the operability of the gravity ventilation system.
2. Use openable windows in conjunction with classroom exhaust vents to facilitate air exchange. Care should be taken to ensure windows are properly closed at night and weekends to avoid the freezing of pipes and potential flooding.
3. Remove all blockages from exhaust vents to ensure adequate airflow.
4. Clean AC filters, personal fans and exhaust vents periodically to prevent excessive dust build-up.
5. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).
6. Ensure leaks are repaired, and repair/replace water damaged building materials. Examine these areas for mold growth. Disinfect areas of water leaks with an appropriate antimicrobial as necessary.
7. Contact a masonry firm or general contractor to repair missing/damaged mortar on exterior brick to prevent water penetration, drafts and pest entry.
8. Seal utility holes around the building exterior, and make repairs to damaged windows.

9. Store cleaning products properly and out of reach of students. Consider storing cleaning products in cabinets with childproof locks.
10. Store and label food appropriately. Refrain from re-using food containers.
11. Consider adopting the US EPA (2000b) document, "Tools for Schools", to maintain a good indoor air quality environment in the building. This document can be downloaded from the Internet at http://www.epa.gov/iaq/schools/index.html.
12. Refer to resource manuals and other related indoor air quality documents for further building-wide evaluations and advice on maintaining public buildings. Copies of these materials are located on the MDPH's website: http://mass.gov/dph/indoor_air

## References


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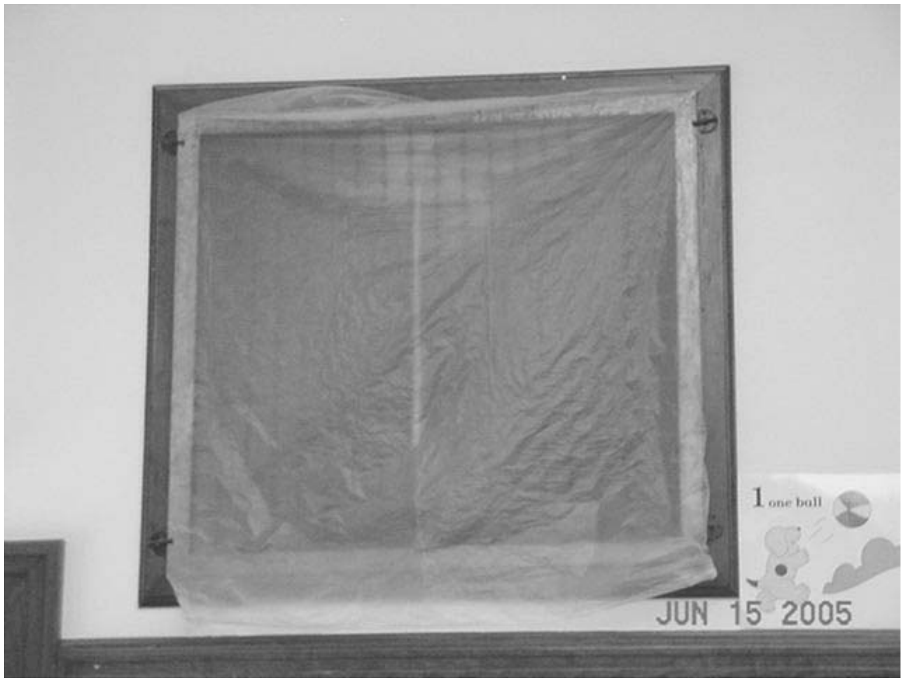
**Picture 1**

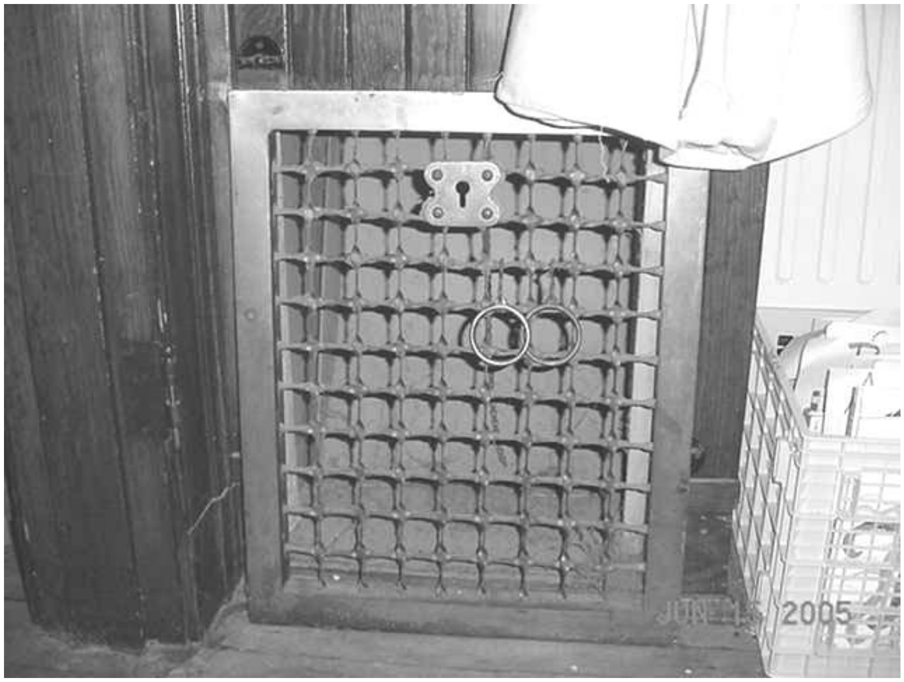



**Sealed supply vent**

**Picture 2**


**Sealed exhaust vent**

**Picture 3**




**Mechanized exhaust vent in coat closet**

**Picture 4**

**Rooftop fan units for mechanized coat closet exhausts**

**Picture 5**


**Blocked mechanized coat closet exhaust**

**Picture 6**


**Plants in classroom**

**Picture 7**


**Utility holes**

**Picture 8**


**Utility hole**

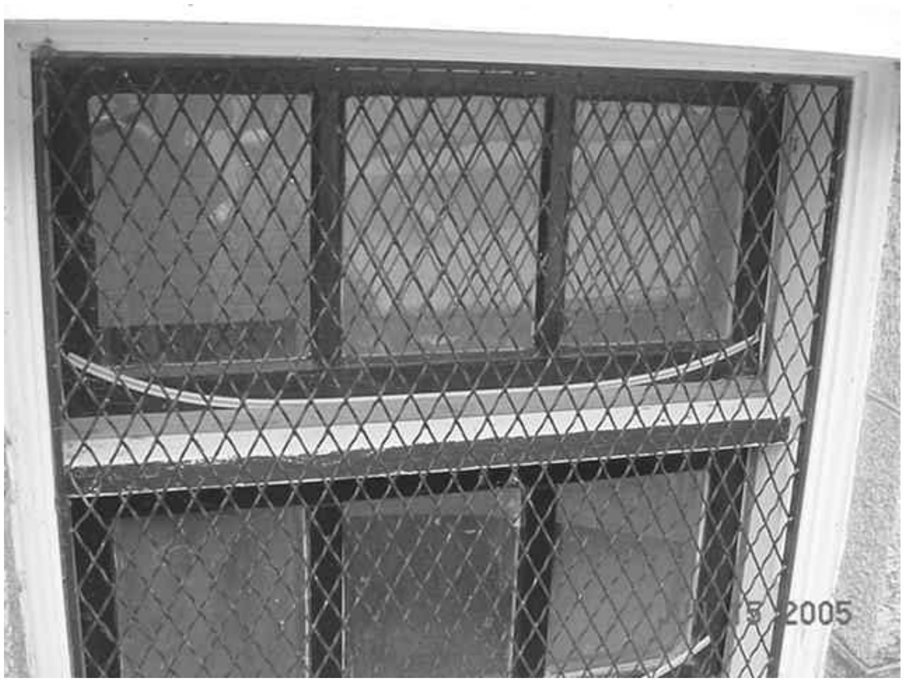
**Picture 9**


**Damaged flashing**

**Picture 10**

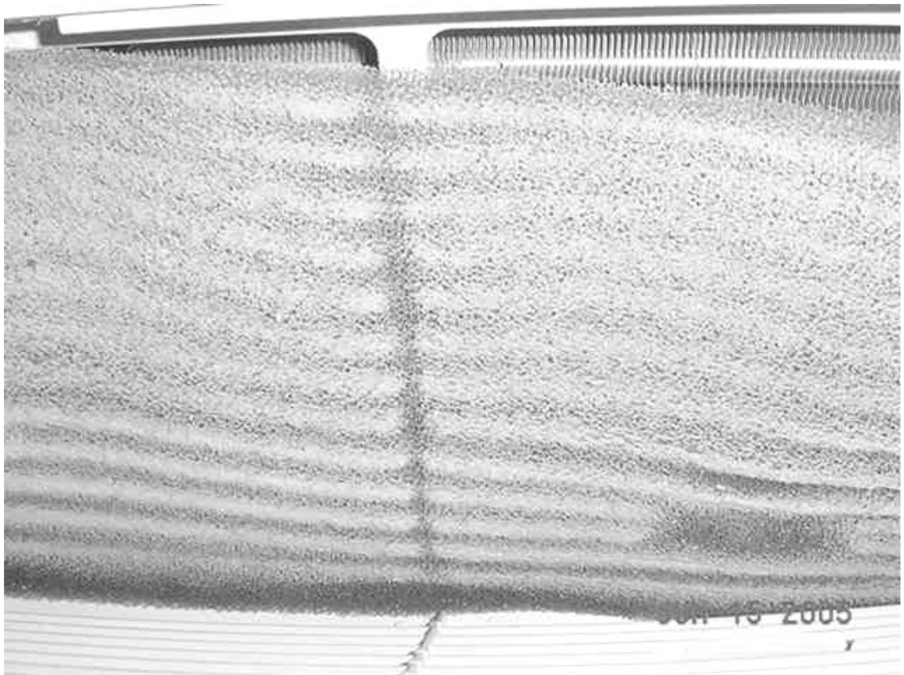
**Missing/damaged mortar**

**Picture 11**




**Gaskets no longer intact**

**Picture 12**

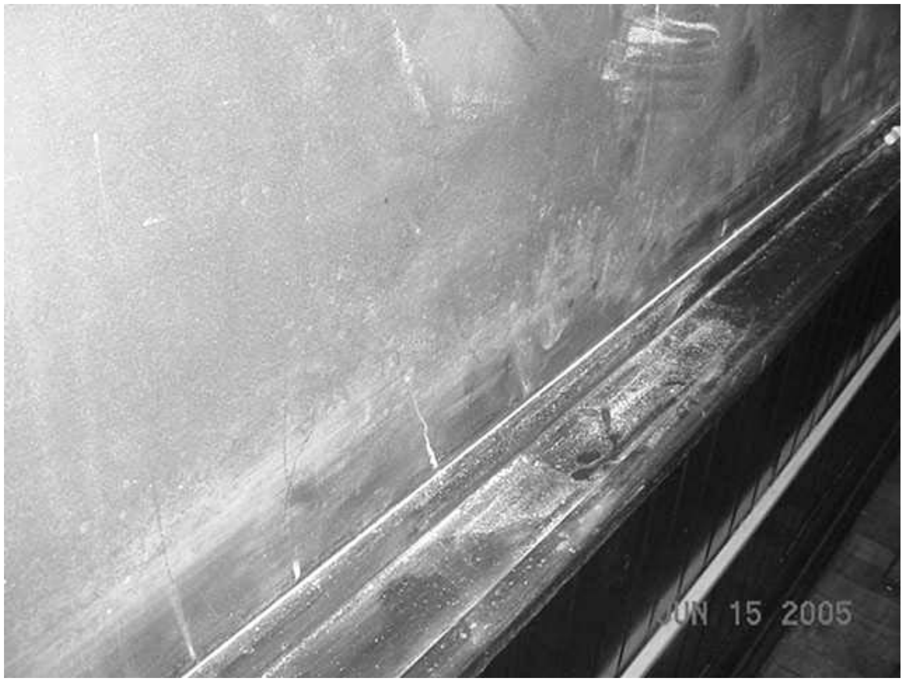


**Dust occluded AC filter**

**Picture 13**


**Dust occluded fan blade to personal fan**

**Picture 14**




**Accumulated chalk dust in tray**

**Uxbridge ELC @ The Good Shepherd School** **Indoor Air Results**

**11 Church St, Uxbridge, MA 01569** **Date: 06/15/2005**

## Table 1

| Location/ Room | Occupants in Room | Temp (°F) | Relative Humidity (%) | Carbon Dioxide (ppm) | Carbon Monoxide (ppm) | TVOCs (ppm) | PM2.5 (µg/m3) | Windows Openable | Ventilation | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Supply | Exhaust | |
| background | | 61 | 50 | 424 | ND | ND | 9 | | | | |
| basement meeting room | 3 | 71 | 50 | 768 | ND | ND | 15 | N | N | N | |
| basement pre K | 11 | 74 | 53 | 823 | ND | ND | 20 | Y # open: 0 # total: 6 | N | N | FC re-use. |
| office | 3 | 66 | 64 | 749 | ND | ND | 10 | Y # open: 0 # total: 0 | N | N | WD-CP, DEM, laminator. |
| 1 OT/PT | 0 | 71 | 49 | 546 | ND | ND | 7 | Y # open: 0 # total: 4 | N | Y wall | window-mounted AC, CD, wet toner copier, window A/C - dusty filter. |
| 2 | 15 | 69 | 46 | 565 | ND | ND | 23 | Y # open: 2 # total: 5 | N | Y wall | Hallway DO, window-mounted AC, PF, FC re-use, window A/C set to fan only. |

ppm = parts per million
µg/m3 = micrograms per cubic meter

AD = air deodorizer
AP = air purifier
aqua. = aquarium

AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials

design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
MT = missing ceiling tile

NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings

sci. chem. = science chemicals
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
VL = vent location
WP = wall plaster

**Comfort Guidelines**

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%

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# Table 1

**Indoor Air Results**

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|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Supply | Exhaust | |
| 3 | 15 | 70 | 43 | 629 | ND | ND | 14 | Y<br># open: 0<br># total: 5 | N | Y<br>wall | Hallway DO, window-mounted AC, PF, cleaners. |
| 4 | 1 | 72 | 48 | 621 | ND | ND | 6 | Y<br># open: 0<br># total: 4 | | Y<br>wall | window-mounted AC, items. |
| 5 | 18 | 73 | 43 | 610 | ND | ND | 10 | Y<br># open: 0<br># total: 6 | N | Y<br>wall | Hallway DO, DEM, PF, plants. |
| 6 | 17 | 71 | 45 | 609 | ND | ND | 11 | Y<br># open: 0<br># total: 6 | N | Y<br>wall | Hallway DO, window-mounted AC, FC re-use, food use/storage, window A/C on fan only setting. |
| 8 | 16 | 72 | 45 | 618 | ND | ND | 10 | Y<br># open: 0<br># total: 6 | N | Y<br>wall | Hallway DO, DEM, PF, FC re-use. |

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